IV. MEETING RESULTS

A. Dispersant Efficacy and Effectiveness for Surface and Deep Ocean Application

Group A initially considered the efficacy and efficiency of surface and subsurface dispersant usage, however, on the second day of the workshop, the group was divided into two subgroups: Group A1 examined the efficacy and efficiency of deep ocean dispersant application, while Group A2 considered the efficacy and efficiency of surface dispersant application.

Group members included:

Group Lead: Joseph Cunningham, Coastal Response Research Center
Recorders: Joe Corsello* & Eric Doe, University of New Hampshire
Tom Coolbaugh*, Exxon Mobil
Craig Carroll#, U.S. EPA
Per Daling, SINTEF
J.T Ewing*, Texas General Land Office
Ben Fieldhouse, Environment Canada
Chantal Guenette*, Canadian Coast Guard
Ann Hayward Walker*, SEA Consulting
Lek Kadeli#, U.S. EPA
Paul Kepkay, Bedford Institute of Oceanography - Fisheries & Oceans Canada
Ed Levine*, NOAA
Zhengkai Li, Bedford Institute of Oceanography - Fisheries & Oceans Canada
Joe Mullin*, Minerals Management Service
Duane Newell*, U.S. EPA Contractor
Bob Pond, USCG
Kelly Reynolds*, ITOPF
Al Venosa, U.S. EPA

*Group Members assigned to Group A2 on Day 2
Group Members who were present for Day 1, but absent during Day 2

Information Required to Make Assessment:

- Spatial location of high, low, and non- effectiveness of dispersant
- Results of continuous water column monitoring, rather than discrete sampling events
- Extent of weathering from surface and subsurface oil
- GPS track routes to see if sampling boats are operating within the vicinity of aerial dispersant application tracks
- Properties of oil on the surface, including thickness and extent of weathering
- Properties of dispersant applied and untreated oil
- 3D visualization of plume
- Location, volume, and trends of plume
- Complete weathering profile of oil
- Accurate volumetric oil flow rate and dispersant application range
- Effect of temperature and pressure on droplet formation and dispersion

- Estimates of contact time and mixing energy
- Dispersability of emulsion after multiple applications of dispersant

Current State of Knowledge:

- Oil emulsion (> 15 – 20% water) is non-dispersible
- Plume is between 1100 – 1300 m deep moving SW direction
- DWH oil high in alkanes, and has a PAH composition similar to South Louisiana reference crude
- Lighter PAHs (< C15) are likely volatilizing
- Viscosity of emulsified oil is between 5500-8500 centistoke
- Emulsion may be destabilizing (50-60%)
- Primary detection method, C3 (fluorometer), only gives relative trends – does not accurately measure concentration of total oil or degree of dispersion

Knowledge Gaps:

- Ability of emulsions to be dispersed with multiple applications of dispersant
- Appropriate endpoint for dispersant application (i.e., how clean is clean?)
- Effectiveness and appropriateness of other dispersant applications (i.e., boat, subsurface, airplane, helicopter)
- Actual range of oil flowrates and composition (i.e., percentage oil, methane)
- Size of plume (volumetric)
- Diffusion of oil components from dispersed droplets into the water column (e.g., aliphatics, PAHs)
- Chemical composition of the plume (i.e., presence of oil, dispersant)
- Extent of surface and resurfacing of dispersed oil

Suggestions to Address Knowledge Gaps:

- Short and long term collection of chemical data (oil and dispersant concentration) at the surface and subsurface
- Measurement of methane concentrations and flowrate throughout the water column
- Analysis of natural vs chemically enhanced dispersion in the subsurface and surface

On day two, Group A was divided into two subgroups; Group A1 examined the efficacy and effects of surface water application, while A2 examined the efficacy and effects of deep ocean application.

Input for RRTs: Group A1 – Surface Application:

1. Surface application of dispersants has been demonstrated to be effective for the DWH incident and should continue to be used.
2. The use of chemical dispersants is needed to augment other response options because of a combination of factors for the DWH incident (i.e., continuous, large volume release).
3. Winds and currents may move any oil on the surface toward sensitive wetlands
4. Limitations of mechanical containment and recovery, as well as *in situ* burning.

5. Weathered DWH oil may be dispersible. Further lab and field studies are needed to assess the efficacy and efficiency and optimal dispersant application (e.g., multiple dispersant applications).
6. Spotter airplanes are essential for good slick targeting for large scale aerial applications (e.g., C-130), so their use should be continued.
7. In order to most effectively use the assets available, the appropriate vessels or aircraft should be selected based on the size and location of the slick and condition of oil. Vessels and smaller aircraft should be used to treat smaller slicks and the weathered DWH oil because they can target more accurately and repeatedly. Larger aircraft should be used for larger fresh oil slicks offshore except in the exclusion zone around the source. A matrix of oil location, oil patch slicks size and condition, dispersant technique/dosage, visual guidance, requirements for success/confirmation has been developed by the dispersant assessment group in Houma incident command. This matrix should be reviewed by the RRTs.

Risks of Input for RRTs:

Dispersants will not be 100% effective. The matrix referenced above contains information to maximize the efficacy of dispersant application on different states of the DWH oil. Dispersants redistribute the oil from the surface to the water column which is a tradeoff decision to be made by the RRT.

Benefits of Input for the RRTs:

Dispersing the oil reduces surface slicks and shoreline oiling. The use of chemical dispersants enhances the natural dispersion process (e.g., the smaller droplet size enhances potential biodegradation). Dispersing the oil also reduces the amount of waste generated from mechanical containment and recovery, as well as shoreline cleanup.

Possible Monitoring Protocols for Surface Water Application:

1. There is a good correlation between Tier 1 SMART observations and Tier 2 field fluorometry data. There has been sufficient Tier 1 and 2 data collected for the DWH incident to indicate monitoring is not required for every sortie.
2. Going forward it is important to now focus on assessing the extent of the 3D area after multiple applications of dispersant at the surface. A sampling and monitoring plan to do this has been developed by the dispersant assessment group based in the Houma command center and initial implementation has begun. The RRT 6 should review this plan.

Input to RRTs: Group A2 – Subsurface Application:

1. The subsurface dispersant dosage should be optimized to achieve a Dispersant to Oil Ratio (DOR) of 1:50. Because conditions are ideal (i.e., fresh, un-weathered oil) a lower ratio can be used, reducing the amount of dispersant required. The volume injected should be based on the minimum oil flowrate, however an accurate volumetric oil flowrate is required to ensure that the DOR is optimized.
2. If we assume a 15,000 bbls/day oil rate and a 1:50 DOR, then actual dispersant flowrate is roughly similar to the current application rate of 9 GPM.

3. To further optimize dispersant efficacy, the contact time between dispersant and oil should be maximized. Longer contact time ensures better mixing of oil and dispersant prior to being released into the water, and should result in better droplet formation.
4. Contact time can be increased by shifting the position of the application wand deeper into the riser, optimizing nozzle design on the application wand to increase fluid sheer, and increasing the temperature of the dispersant to lower viscosity.
5. Effectiveness should be validated by allowing for a short period of no dispersant application followed by a short time of dispersant usage to look for visual improvements in subsurface plume.

Risks of Input for RRTs:

Dispersants are never 100% effective. The flow rate of oil out of the damaged riser is not constant, and significant amounts of methane gas are being released. Because the effective DOR is a function of oil flow rate, changes in the oil flow rate may significantly impact the actual DOR. If the DOR is too low, dispersion may not be maximized, while if it is too high, dispersant will be unnecessarily added to the environment. Assumptions are based on knowledge at standard temperatures and pressures (STP), while conditions at the riser are significantly different. Group members suggested that the oil escaping the damaged riser may be in excess of 100°C, and it is unclear what effect this has on the dispersant, or the efficacy or effectiveness of droplet formation. These conditions may drastically alter fluid behavior. Finally, there is an opportunity cost of changes to application wand position and development and deployment of a new nozzle.

Benefits of Input for the RRTs:

When optimized, subsurface dispersant application may reduce or eliminate the need for surface dispersant application, and will reduce surfacing and resurfacing of oil. Optimized subsurface dispersant application will likely promote formation of smaller, more stable droplets of oil, theoretically allowing quicker biodegradation.

Possible Monitoring Protocols for Subsurface Application:

1. Measurement should be made on the surface and subsurface to detect dispersant and dispersed oil to gauge the effectiveness of subsurface dispersant application. Currently, no known technique exists for accurately measuring part per billion concentrations of dispersant in seawater, and novel applications of GC-MS/GC-FID or UVFS + LISST may be required.
2. Tier 1 (SMART) visual monitoring at the surface with quantification of oil with aerial remote sensing
3. Visual monitoring may be able to qualitatively demonstrate differences between dispersant application and no application (e.g., plume shape, color).

B. Physical Transport/ Chemical Behavior of Dispersed Oil

Group B was focused on the physical transport and chemical behavior of dispersed oil. While the initial goal was to look at these characteristics for chemically dispersed oil, the scope of the deepwater horizon incident required looking at both chemically and naturally dispersed oil.

Group members included:

Group Lead: Bruce Hollebone, Environment Canada
Recorder: Tyler Crowe, Coastal Response Research Center
Les Bender, Texas A&M
Mary Boatman, Minerals Management Service
Michel Boufadel, Temple University
Robert Carney, Louisiana State University
Jim Churnside, U.S. EPA
Greg Frost, U.S. EPA
Jerry Galt, Genwest
Buzz Martin, Texas General Land Office
Allan Mearns, NOAA
Scott Miles, Louisiana State University
Erin O'Riley, Minerals Management Service
Jim Staves, U.S. EPA

Information Required to Make an Assessment and Knowledge Gaps:

- Contact efficiency between dispersant and oil at the sea floor
- Release rate of oil and gas
- Dispersion efficiency at injection point on sea floor
- Mixing energy at injection point on sea floor
- Effects of increased pressure and temperature on dispersion efficiency
- Temperature of released oil
- Degree or rate of weathering of oil in rising plume (e.g., dissolution, vapor stripping)
- Emulsion formation and dispersion in the rise zone, under pressure
- Destabilization of emulsions as pressure decreases
- Biodegradation rate on droplets at pressure and at bottom temperature
- Sedimentation of dispersed oil from depth
- Biological uptake, particularly in demersal and benthic organisms
- Surface Langmuir circulation potential for mixing
- Surface advection rates versus oil discharge to determine buildup potential
- BTEX levels above oil slick
- Suppression of airborne VOCs when using dispersants
- Airborne concentrations of 2-butoxy ethanol from spring
- Atmospheric breakdown and toxicity of 2-butoxy ethanol and other products
- Improved NEBA for dispersant use

Current State of Knowledge:

- Surface models are effective and continuously improving
- SMART protocols are improving
- Increase of sampling at depth
- Well researched region (oceanographic and ecological studies)
- Well established baseline data
- Airborne application protocols are established

Suggestions to Address Knowledge Gaps:

- Review Norwegian experiments (Deep Spill, 2000)
- Review literature on IXTOC I
- Increase in remote sensing of the dispersed area (check for oil resurfacing)
- Use of smaller grid sizes or nested grids on models
- Increased offshore surface sampling independent of SMART at fixed stations in the operational zone
- Establishment of criteria for discontinuance of dispersant operations
- Further research on the contact efficiency between dispersant and oil at the subsurface injection point
- Better understanding of release rate and temperature of oil and gas
- Quantification of mixing energy at injection point
- Better coupling between offshore (ocean/pelagic) and onshore (estuarine or riverine) hydrodynamic models (LaGrangian vs. Eulerian)
- Laboratory investigation of effects of elevated pressure and temperature on dispersion efficiency at depth (e.g., study in pressure cells)

Input for RRTs:

1. Create an on-scene environmental review committee to advise SSCs that will be responsible for providing immediate operational and scientific advice, and aid in dispersant decisions. This committee should be comprised of government agencies and academia that meet regularly.
2. Clearly define geographic area/water volume of concern. This will improve estimates for scale of impact (1st order approximation). This is important for NEBA analysis, and is based on current application rates, and maximum concentrations in the water volume.
3. Establishment of a more comprehensive sampling and monitoring program to understand transport of oil on the surface and potential for long-term increases to TPH, TPAH, oxygen demand, or lowering of DO with continued dispersant application. This could be done by implementing off-shore water (first 10 m) monitoring stations (e.g., fixed stationary positions such as other drill rigs).

Risks of Input for RRTs:

Continued dispersant use trades shoreline impacts for water column impacts. This increases the uncertainty of the fate of the oil, and potentially increases the oil sedimentation rate on the bottom.

Benefits of Input for the RRTs:

Continued dispersant use reduces the threat distance, protects shorelines, likely increases the biodegradation rate of the oil, inhibits formation of emulsions, reduces waste management, and potentially reduces buildup of VOCs in the air.

Possible Monitoring Protocols for Subsurface Application:

1. Measure size and shape of the plume with and without subsurface injection of dispersant in order to have a better understanding of the efficacy. Sonar

monitoring of plume size and morphology (tilt) can be used; increases in plume size or longer "tail" of droplets suggest greater dispersion
2. Additional monitoring in the rising plume at a variety of depths to improve transport modeling and development of boundaries and constraints on estimates.
3. Additional subsurface monitoring of water temperature, particle size distribution, fluorescence monitoring of dispersant concentration, and total petroleum hydrocarbons (TPH) to define subsurface plume concentrations and boundaries.
4. Increase surface layer water quality monitoring (profile of upper 10 m) to address concerns of cumulative loading of water with oil and dispersant. Size of the monitoring zone will vary with advection and dispersant application. Should monitor for TPH, PAHs, dissolved oxygen, salinity, temperature, biological oxygen demand (BOD), VOA, and if feasible, surfactant monitoring and toxicity testing.
5. Further air monitoring of surface water quality zone to gain a better understanding of volatilization and risk to responders. Monitoring should include BTEX and VOC concentrations, and while COREXIT 9527 is being used, 2-butoxy ethanol.

C. <u>Biological Effects of Dispersants on Deep Ocean Species</u>

Group C discussed exposure pathways of dispersants applied to the subsurface and subsequent biological effects. Group members included:

Group Lead: Zachary Magdol, Coastal Response Research Center
Recorder: Mike Curry, Coastal Response Research Center
Adriana Bejarano, Research Planning Inc.
Richard Coffin, Naval Research Laboratory
William Conner, NOAA Office of Response and Restoration
Charlie Henry, NOAA, Scientific Support Coordinator for USCG District 8
Ken Lee, Environment Canada
Jeffrey Short, Oceana
Ron Tjeerdema, University of California

<u>Information Required to make assessment:</u>

- Receptor species/species at risk
- Identify species at risk including their migration, feeding habits, life histories, reproductive strategies/recruitment
- Dispersant effect on oxygen and other electron acceptor availability on key biogeochemical cycles in the deep water ecosystem
- Assess the maximum rates of dispersant application to balance treatment of the spill and a low environmental impact
- Determine the impact on nutrient recycling, general efficiency of food chain
- What is the particle size distribution as a function of depth, and if these changes affect key elemental absorption and feeding strategies
- Oil biodegradation rates, microbial community structure and ecosystem function in the presence and absence of the dispersant
- Evaluate the seasonal and spatial variation in the deep ocean oxygen demand in the presence and absence of the dispersant

- Scavenging particle interactions, oil-mineral aggregate formation at source and throughout water column
- Vertical and horizontal transport dynamics of deep water ocean currents for an overview of the oil and dispersant transport and dilution
- Unknown indirect effects (e.g., persistence) on the food chain and key elemental cycles
- Biogeochemical and habitat data about ecosystems near natural deep water petroleum seeps to evaluate the cycling rates and community structure
- Percent effectiveness of the seafloor dispersant application relative to the surface application
- Determine the changes in the petroleum layer through the water column with application of the dispersant
- Changes in microbial degradation due to selective metabolism from addition of dispersants (e.g., is there a preferred dispersant degradation that will pathway that will limit petroleum degradation?)
- Effectiveness of natural dispersion
- Knowing the downstream flux of oil residue from the spill to the seafloor to contribute to a net balance of the oil fate

Current State of Knowledge:

- Minerals Management Services, Gulf of Mexico deep water studies/reports: http://www.gomr.mms.gov/homepg/regulate/environ/deepenv.html
- Natural hydrocarbon seepage in the Gulf of Mexico approximately 40 million gallons per year
- Some knowledge and past studies on deep water species in the Gulf of Mexico
- Preliminary modeling
- Preliminary monitoring data (Fluorometry data, Particle size analysis, Temperature, Salinity, D.O., Hydrocarbon, Acute toxicity , Acoustic data, sonar, Genomics)
- None of the information listed above is considered “complete”

Knowledge Gaps:

- Preliminary models not validated
- Life history of benthic biota
- Migratory patterns and residence time of deep water species
- Microbial degradation rates on deep ocean hydrocarbon seeps
- Dispersant and dispersed oil byproducts
- Chronic toxicity of benthic biota
    - Comparison of bioaccumulation/bioavailability between different droplet sizes
    - Comparison of toxicity and environmental impact of natural vs chemically enhanced dispersed oil
- Species avoidance of oil

Suggestions to Address Knowledge Gaps:

- Formulation of biogeochemical rates with respect to fuel transport and sedimentation

- Early life stage studies, laboratory or cage studies
- Robust toxicity studies for deep water species
- Spatial and temporal variation in the ecosystem oxygen and alternate electron acceptor availability

<u>Input for RRTs:</u>

1. Dispersant risk assessment should consider volume of DWH incident relative to natural seepage
2. There is a net benefit to continued subsurface dispersant use and application should continue

<u>Risks of Input for RRTs:</u>

Dispersant use increases the extent of biological impacts to deep water pelagic and/or benthic organisms, including oxygen depletion, release of VOCs into the water column, and toxicity. This may lead to changes in the diversity, structure and function of the microbial community, leading to changes in trophic level dynamics and changes to key biogeochemical cycles.

<u>Benefits of Input for the RRTs:</u>

- Surface water column and beach impacts vs. vertical water column impacts
- Observed reduction in volatile organics at surface
- Enhances the interaction between oil and suspended particulate material
- Accelerated microbial degradation through increased bioavailability
- Rapid recovery of downward sulfate diffusion and upward methane diffusion related to shallow sediment geochemistry
- Based on current knowledge, subsurface dispersant use confines the aerial extent of impact
    - Current impact zone is less than 50 km radius
- Reduction in emulsified oil at the surface
- Reduction of phototoxic impacts

<u>Possible Monitoring Protocols for Surface Water Application:</u>

1. Robust deep ocean toxicity studies
    - Application of research done with acute toxicity on foraminifera, possibility of chronic studies (LC50, EC50)
    - Identify control areas, in terms of system ecology, physical ocean properties, and biogeochemical parameters
    - Cage studies in the plume
    - Identify surrogate/indicator species for impacts over a range of trophic levels
    - Identify key species of concern (migratory species)
    - Microbial genomics to survey changes in the community structure that changes key elemental cycles
    - Long term biological effects for resident species with baseline information
2. Biogeochemical monitoring
    - Petroleum degradation rates (C14 labels)

- o Microbial production and function (3H thymidine/leucine and Genomics)
- o Community diversity (16S RNA)
- o Background parameters (DOC, POC, DIC, concentration and $\delta^{13}C$)
- o Bioavailability of the oil as a function of particle size

3. Physical/chemical parameters
   - o UV fluorometry (Including FIR)
   - o Monitor the particle size distribution of the oil as function of space and time (LISST particle counters)
   - o Current velocity (ADCP)
   - o Chemical properties CTD (oxygen, salinity, pH, SPM)
   - o Chemical and source properties of the oil as a function of space and time (GC-MS and IRMS)
   - o Potential of acoustic monitoring (3.5 and 12 khz)

D. **<u>Biological Effects of Dispersants on Surface Water Species</u>**

Group D focused on the effects of surface dispersant application on species in the top ten meters of the water column. Group members included:

Group Lead: Nicholle Rutherford, NOAA
Recorder: Heather Ballestero, University of New Hampshire
Carys Mitchelmore, University of Maryland
Ralph Portier, Louisiana State University
Cynthia Steyer, USDA
Mace Barron, U.S. EPA
Les Burridge, St. Andrews Biological Stn, Fisheries and Oceans Canada
Simon Courtenay, Gulf Fisheries Centre, Fisheries and Oceans Canada
Bill Hawkins, Gulf Coast Research Laboratory, University of South Mississippi
Brian LeBlanc, Louisiana State University
Jeep Rice, NOAA
Doug Upton, MS DEQ
Terry Wade, Texas A&M University

<u>Information Required to make assessment:</u>

- Spatial location of oil, dispersants, and species
- The levels of concern need to be noted (e.g., sensitive species life stages, exposure pathways, LC50's oil and dispersant constituents)

<u>Current State of Knowledge:</u>

- The oil is being dispersed in the top ten meters of the water column from surface dispersant application (fluorescence methods)

<u>Knowledge Gaps:</u>

- Effectiveness of dispersant
- Long term effects of dispersant exposure (carcinogenicity)
- Dispersed oil effects in an estuarine/riverine/pelagic environment
- Bioavailability, bioaccumulation

<u>Suggestions to Address Knowledge Gaps:</u>

- Develop a clearinghouse to facilitate access to baseline data being collected

- Know dose of exposure, effects, species present and tradeoffs with habitat protection
- Understand differences between dispersed vs. non-dispersed oil

Input for RRTs: Effects of Dispersant in the top 10 M.

1. Surface application of dispersants is acceptable. Transferring the risk from the surface to the top 10 m is the lesser of the many evils.
2. Additional monitoring is required to better model where dispersed oil is going. Long term (monthly) monitoring is required at a minimum, and should be conducted in a grid formation inshore to open ocean. Passive samplers (i.e., SPME) should be used in selected areas, while a active water sampling program should be implemented to measure dispersant and dispersed oil, dissolved oxygen, and standard CTD + chlorophyll concentrations, as well as selected bioassays.

Possible Monitoring Protocols:

1. Monitor below 10 m
2. Monitor surface to bottom across a transect from the shore to source
3. Deploy semi-permeable membrane device (SPMD), passive sampling, or oysters
4. Monitor concentration and exposure time to get a better understanding of effective dose
5. Use state-of-the-art toxicity tests